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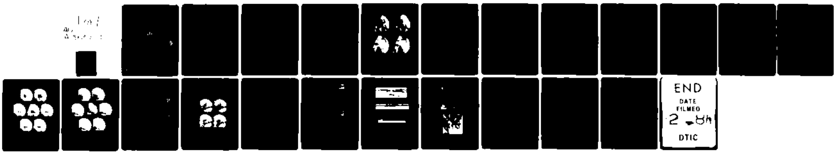

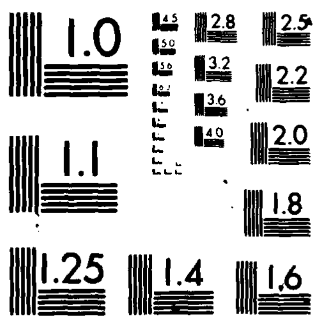

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INCREASED SENSOR SIMULATION CAPABILITY AS A RESULT OF IMPROVEMENTS TO THE DIGITAL LANDMASS SYSTEM (DLMS) DATA BASE

Dr. Marshall Faintich
Physical Scientist
Advanced Technology Division
Systems and Techniques Directorate
Defense Mapping Agency Aerospace Center
St. Louis Air Force Station, Missouri 63118

Mr. John Gough
Physical Scientist
Scientific Data Department Techniques Office
Defense Mapping Agency Aerospace Center
St. Louis Air Force Station, Missouri 63118

ABSTRACT

The Defense Mapping Agency is producing digital culture and terrain elevation data bases to support advanced aircraft simulators. Data base analyses and sensor simulations have led to improvements in the specifications for these data bases, and have been used to define parameters to be included in a prototype data base designed to support visual and other high resolution sensors. These improvements and new parameters are discussed, and sensor simulations and data base displays are shown.

INCREASED SENSOR SIMULATION CAPABILITY AS A RESULT OF IMPROVEMENTS TO THE DIGITAL LANDMASS SYSTEM (DLMS) DATA BASE

INTRODUCTION

In order to support advanced aircraft simulators by providing an improved low level radar training capability offered by digitally generated radar landmass images, the Defense Mapping Agency (DMA) is producing digital culture and terrain elevation data bases. The DMA has conducted extensive investigations in digital sensor simulation for the purpose of establishing an effective editing and analysis capability of these data bases (Faintich, 1979, 1980). The DMA is also pursuing advanced techniques for data base production through its research and development program. As a result of the technology developed for aircraft radar simulator support, multi-sensor scenes and data bases are being developed for both simulators and input to reference guidance systems. The primary purpose of this paper is to describe results obtained from improvements to the Digital Landmass System (DLMS) Data Base and compare these results with both actual and previously simulated sensor imagery. This paper does not necessarily represent DMA policy, nor is it a commitment to produce data in a particular manner.

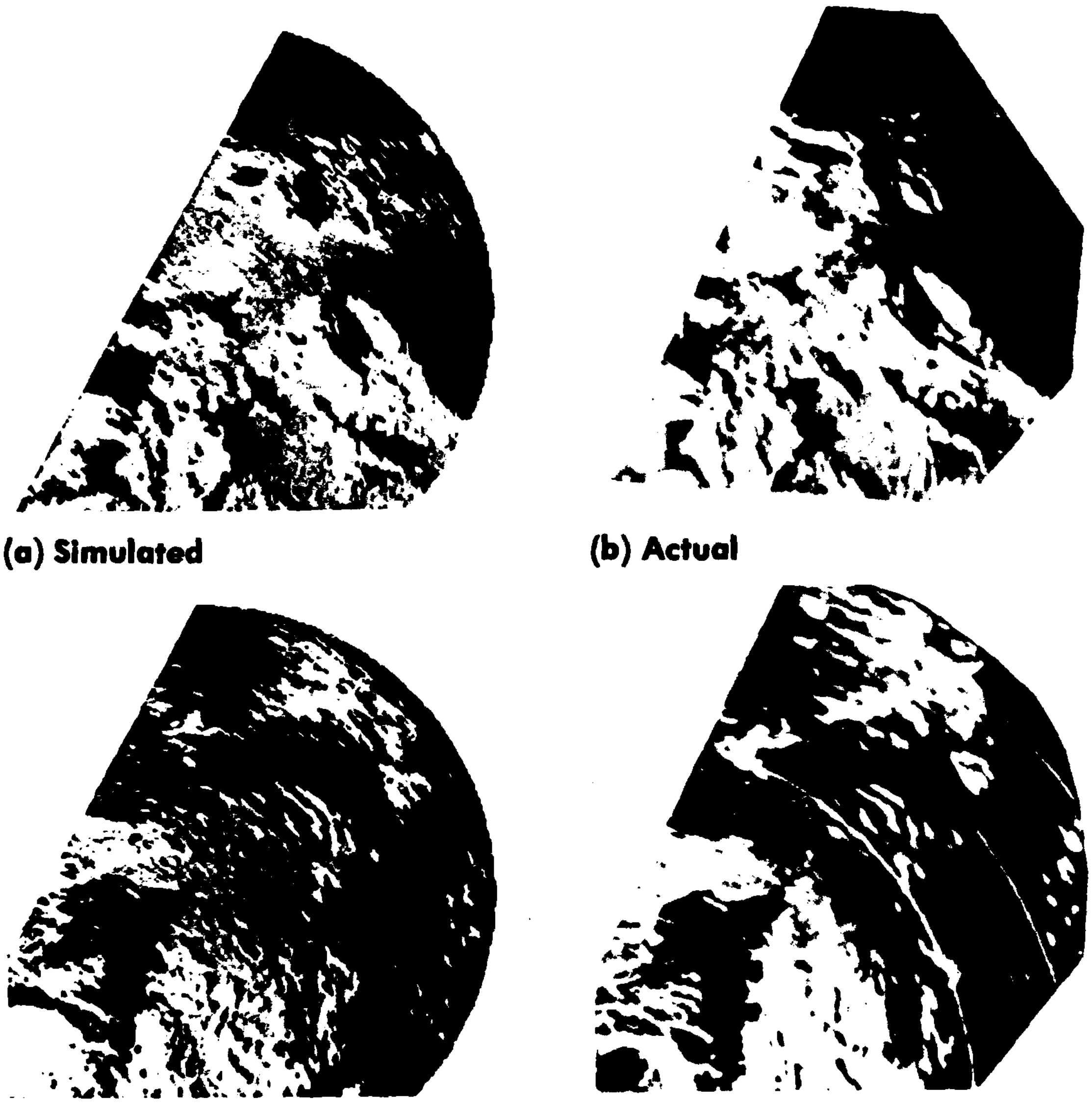
CURRENT AND ANTICIPATED DATA BASE CONTENT

The current (July 1977 specification) DMA standard production data bases (Level I) contain large area cultural information, and digital terrain data sampled at a three second interval. The cultural data consists of point, linear, and areal features described by characteristics such as surface material category, generic

identification, predominant height, structure density, and percentages of roof and tree cover. The cultural data is in lineal (planimetric boundary) format and although feature sizes may vary depending upon local circumstances, the data reflects a resolution on the order of 500 feet. Smaller features are aggregated into homogeneous features described by predominant characteristics. The current high resolution (Level II) data bases contain small area cultural information, and digital terrain elevation data sampled at a one second interval. This translates to a resolution of about 100 feet, with smaller features also aggregated. Detailed information is available in Reference 2, "Product Specifications for Digital Landmass System (DLMS) Data Base."

The terrain elevation data is produced by contour digitization from charts or directly from stereo pairs of photographs using advanced analytical stereoplotters. The cultural data is produced from both charts and photographs with a much higher level of manual effort required in order to perform the complex feature analysis. Because of the labor intensive nature of the task, the production of Level II cultural data ranges from 10 to 100 times the production cost of Level I data, depending on the area. The current Level I data base program covers roughly 20 million square nautical miles, with estimated data base completion dates in the 1985 to 1990 time period. Level II data is programmed only for small selected areas of interest.

The DLMS data bases have been shown to be adequate for support of long and medium range radar simulation (see Figure 1), and for short range radar simulation where Level II data is available. In addition, these data bases have shown some



(a) Simulated

(b) Actual

(c) Simulated

(d) Actual

Figure 1. Level I DLMS Radar Simulations: Las Vegas, Nevada (a) Long Range (85 n.m.) Simulation versus (b) Actual Radar; (c) Medium Range (32 n.m.) Simulation versus (d) Actual Radar Scope Photography

applicability for multi-sensor simulation. As integrated chip and micro-computer technology improves, however, on-board multi-spectral electro-optical navigation sensors continue to acquire and display terrain and cultural information with ever increasing resolution approaching that of a visual response. Training is required in the use of advanced aircraft displays, including forward looking infrared systems, low light level television, ultra-high resolution and real-time synthetic aperture radar, as well as an increased demand for visual training associated with low altitude mission profiles. Technology improvements will also allow greater realism in advanced simulators, and the demonstrated effectiveness of present simulators is driving requirements for simulators to support the new generation of navigation sensors.

In addition, the commitment of the DOD to the development of various types of weapon system guidance correlators are demanding new support data. Correlation may be made against pre-stored computer generated reference scenes for optical, infrared, microwave, conventional and synthetic aperture radar, and ultra-violet electro-optical sensors.

A crucial component in support of these new navigation/guidance systems is the ability to provide adequate digital data bases that describe a variety of global ground truth conditions. Both static and time-varying information such as texture, thermal and near-infrared properties, precise geometric properties, road patterns, population and traffic density patterns, and atmospheric weather data will be required in addition to current DLMS feature descriptors. Along with new types of feature descriptors, increased resolution and level of detail will be required.

Initially, much of the advanced data descriptors will not be cost effective or possible to collect and will have to be modeled from known parameters. As automated feature analysis and extraction techniques become developed, an increasing amount of these data types will be described more closely in agreement with their physical characteristics and will be included in the cultural data base. As an interim procedure, or for data base areas where higher resolution data is required only for increased data content and appearance, and not for reasons of precise ground truth, computer techniques such as texturization (Bunker, 1978) and synthetic feature break-up (Faintich, 1979) allow for the production of large data base coverage using existing techniques.

EVOLUTION OF DATA BASE PRODUCTION

The labor intensiveness of the present digital data base production process and the worldwide extent of DLMS requirements has led DMA to explore automation as a means of decreasing production costs. This is being accomplished within the technical base existing at DMA and via research and development programs through academic, industrial, and governmental institutions. Initial goals to increase production of current DLMS Level I and II data is being addressed by the implementation of specialized automated processing systems and computer assisted photo-interpretation stations. In order to establish the capability to produce anticipated data types and resolutions required by 1985, the DMA is expanding its Image Understanding program for the technology base required to support the development of an interactive, semi-automated feature analysis production system.

For purposes of quality control and data base applicability investigations, the DMA is developing the Sensor Image Simulator, a very high speed data base edit station and static scene simulator that allows for interactive query of individual features in the simulated sensor scene to determine the corresponding data base elements responsible for the simulated features.

In advance of the integration of future automated feature analysis techniques, the DMA has refined the DLMS data base specifications commensurate with current production capabilities to better support sensor simulation. The 1974 data base specifications were revised in July 1977, and the DMA is currently producing a prototype data base to support high resolution sensors.

1977 DLMS DATA BASE SPECIFICATION REVISION

As a result of an intense test and evaluation of the data produced for USAF Project 1183 (Robinson et. al, 1979), the DLMS data base specifications were changed to include the following major revisions:

a. standardization of feature descriptors where actual differences are insignificant;

b. decrease in the minimum size for strong reflectors;

c. decrease in the minimum size for building groupings with significant height differences;

d. increase in the minimum size for poor reflectors;

e. decrease in the minimum size for open areas with an urban area;

f. expansion and clarification of unique feature specifications;

g. reduction from six levels (IA, IB, IIA, IIB, IIIA, IIIB) to two (I, II);

h. standardization of percent roof cover descriptor;

i. portrayal of dense trees in urban areas;

j. increase of feature identification codes from 48 to 255;

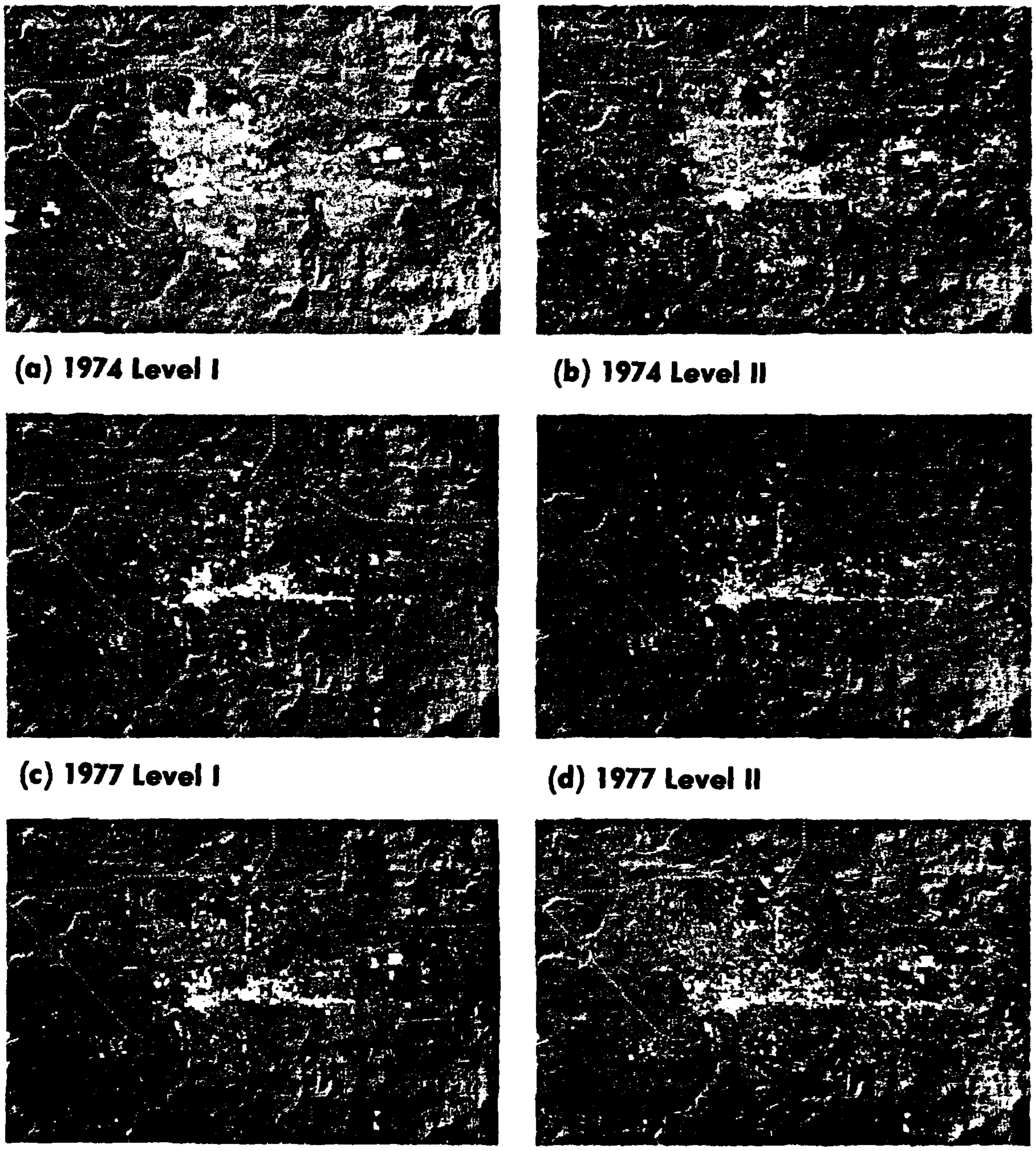
k. portrayal of certain regional features apparent on low altitude radar;

l. description of seasonal and natural effects such as sea states;

m. portrayal of permanent snow and ice.

For comparison between the data bases, DLMS cultural and terrain data over Spokane, Washington, was chosen. This particular area was chosen because of existence of both 1974 and 1977 specification Level II data over a large area, availability of actual short range radarscope photography, and exclusion of this data in the test and evaluation study that resulted in the 1977 revisions. The comparisons between Levels I and II data may be somewhat biased, however, as the Level I data was produced using the Level II as a base. Although this is a standard technique, Level II data over a large area is usually unavailable to be used as a base, and the Level I data is compiled directly from feature analysis source materials. Figure 2 shows on-line 110 meter resolution data base displays of this area, wherein shaded relief of Level I terrain is shown, and gray levels represent radar reflectivity potentials. The synthetic break-up (SBU) data bases were produced by generation of random cultural, tree cover, and background features with descriptors normally distributed about original predominant values within homogeneous areal feature boundaries, based upon the percentages of tree and roof cover.

Inspection of these displays clearly shows the additional features portrayed due to decreased standards for strong and significant reflectors (Level I) and the the reduction of features portrayed due to increased standards for poor reflectors (Level II). Also, the reflectivity potential for general residential/commercial areas is reduced, probably due to standardization of height descriptors. The SBU displays show the breakup of the areal features into background, trees, and brighter cultural reflectors due to elimination of adjustment for tree cover within a homogeneous area. Also of particular interest is that the differences



(a) 1974 Level I

(b) 1974 Level II

(c) 1977 Level I

(d) 1977 Level II

(e) 1977 Level I SBU

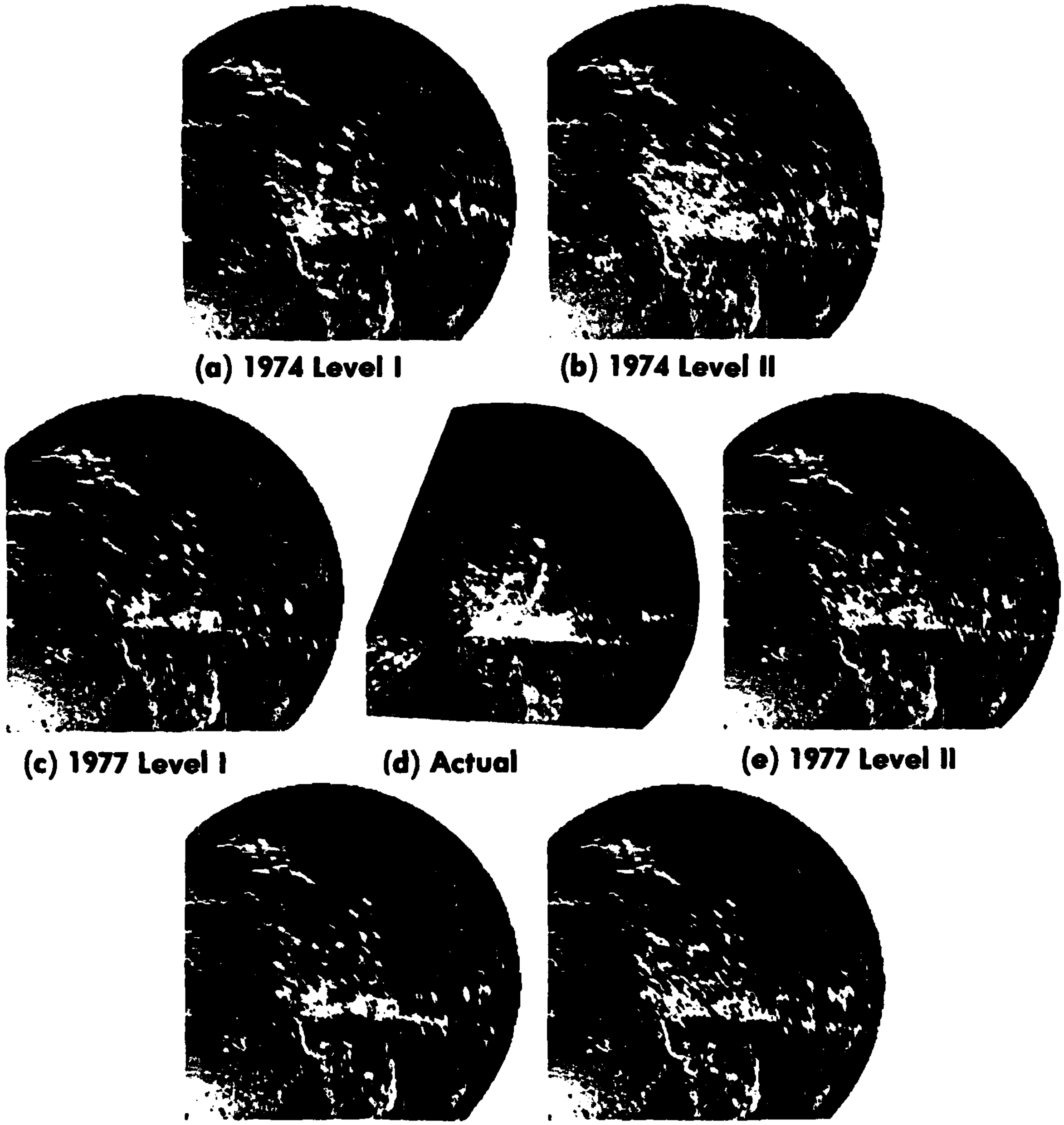
(f) 1977 Level II SBU

Figure 2. On-Line Data Base Displays: Spokane, Washington

between the 1977 Levels I and II displays at this resolution (for $\geq$ 15 n.m. radar scope displays) are much less than in the 1974 displays. This raises questions as to the need of Level II data at this resolution for short range simulation. For short/short range radar displays ($<$10 n.m.), the differences are much more apparent.

Now consider Figures 3 and 4. Radar simulations from the six data bases are compared with actual radar scope photography on 15 and 22 n.m. range displays. The gain settings for all six of the simulations in each figure are identical (except for Figures 4f and 4g) and were chosen for the best match between actual and the 1974 data base simulations. Note that the 1977 data bases provide for a better comparison with actual, especially better for Level I. In addition, for both Levels I and II, the general residential/commercial homogeneous returns are either missing under insufficient gain or appear as large homogeneous "blobs" without the benefit of SBU. The SBU simulations shown in Figures 4f and 4g have slightly lower gain settings to better match actual returns.

Figures 5 and 6 show data base displays and radar simulations, respectively, for the 1977 data bases with and without SBU at a resolution of 25 meters for 5 n.m. short/short range displays. Note that the differences between Levels I and II are quite apparent, and that the SBU technique continues to add to the effect of realistic simulation of the large areal features.



(a) 1974 Level I

(b) 1974 Level II

(c) 1977 Level I

(d) Actual

(e) 1977 Level II

(f) 1977 Level I SBU

(g) 1977 Level II SBU

Figure 3. Short Range (22 n.m.) Radar: Simulations Using Various Data Bases versus Actual Radar Scope Photography

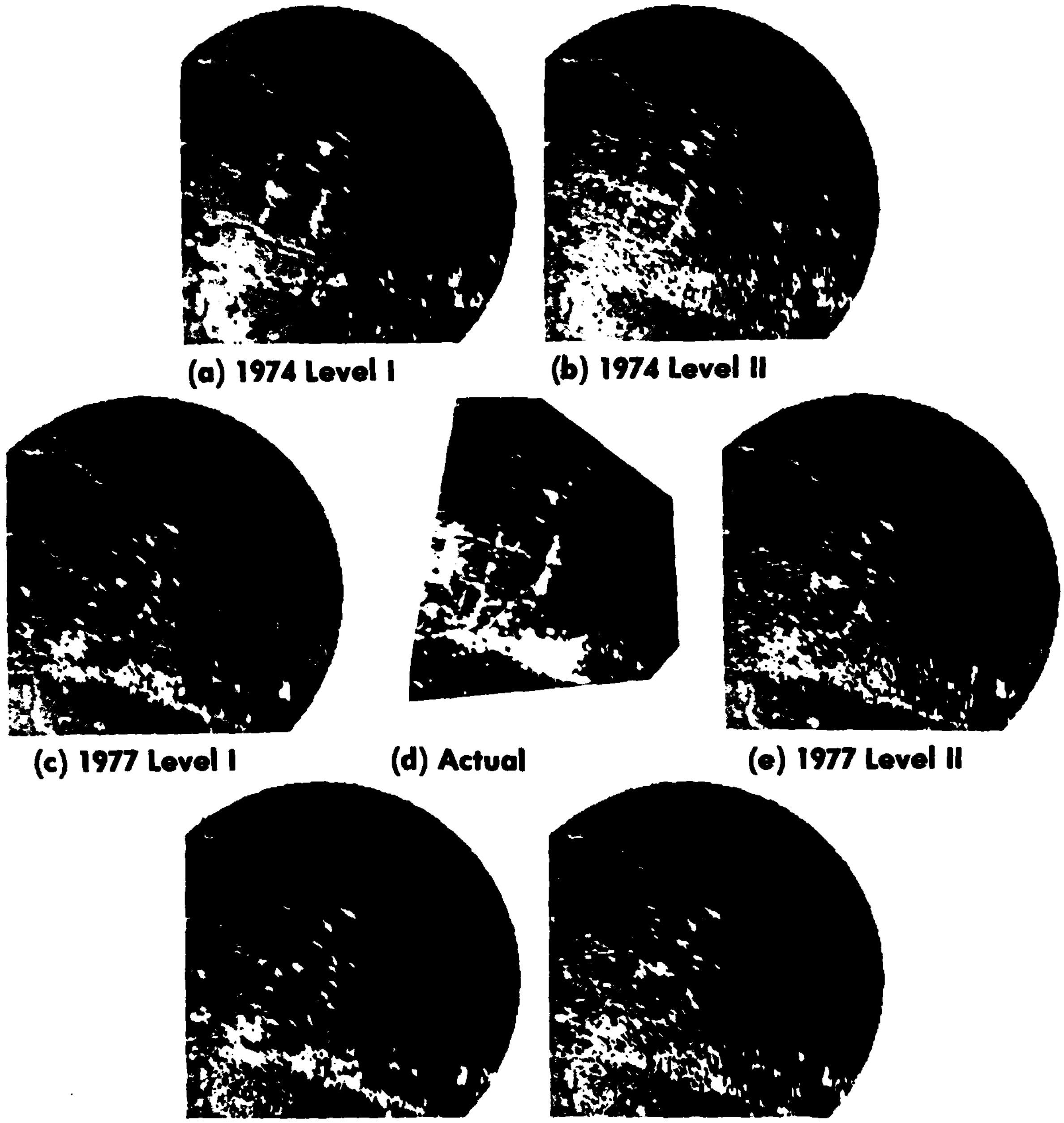
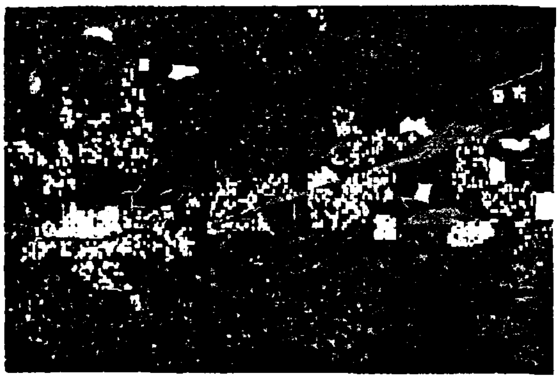


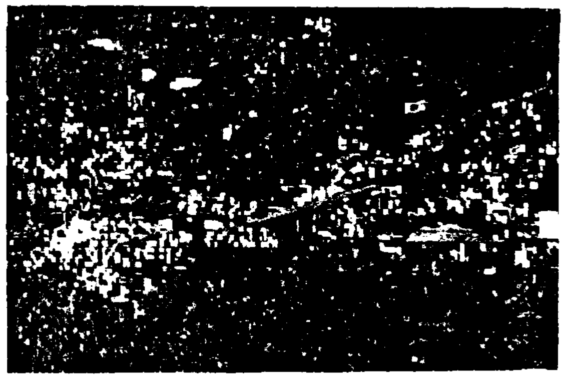
Figure 4. Short Range (15 n.m.) Radar: Simulations Using Various Data Bases versus Actual Radar Scope Photography

(a) 1977 Level I

(b) 1977 Level II



(c) 1977 Level I SBU

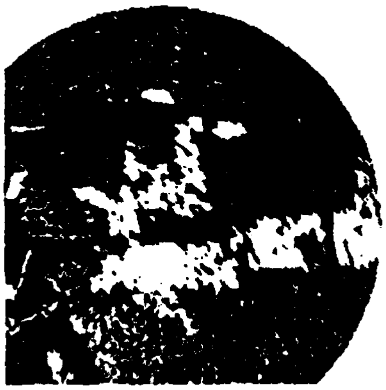


(d) 1977 Level II SBU

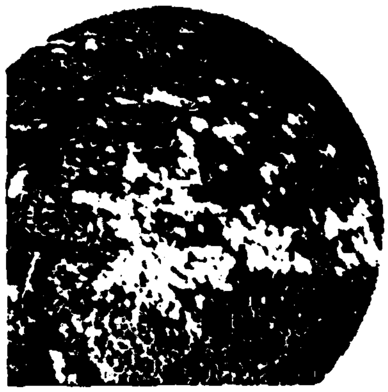
Figure 5. On-Line Data Base Displays: Spokane, Washington High Resolution Grid (25 meter)

(a) 1977 Level I

(b) 1977 Level II



(c) 1977 Level I SBU



(d) 1977 Level II SBU

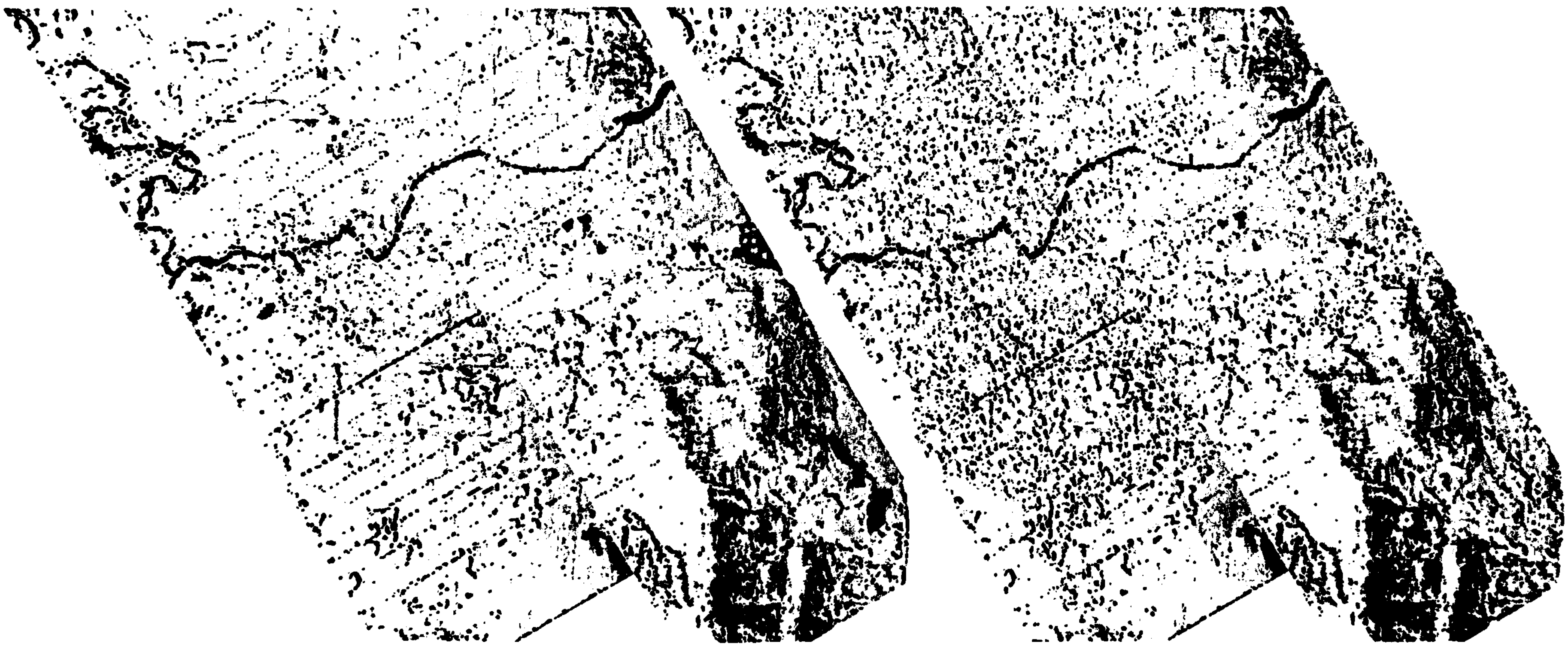
Figure 6. Short/Short Range (5 n.m.) Radar Simulations

One may conclude from these studies that unless short/short range simulation is required for high precision conventional radar mission training, Level I DLMS data may be sufficient, and that the technique of synthetic break-up adds to the realism of the simulation. For areas surrounding high fidelity training data bases, synthetic break-up may be used to generate compatible frequency data for blending purposes.

When considering non-conventional radars such as Synthetic Aperture Radar (SAR), the high precision of the Level II data may be required for much longer ranges. Figure 7 shows SAR simulations from the same 25 meter resolution data bases. Note that the effect of synthetic break-up adds greatly to the realism in the simulations.

PROTOTYPE HIGH RESOLUTION DATA BASE

The 1977 revision of the DLMS data base specifications includes descriptors that may not be needed for radar systems, but are certainly of value for simulation of other sensors. Figure 8a is a visual simulation of Port Angeles, Washington, and snow-capped Mt. Olympus from a 10,000 foot altitude, and Figures 8b and 8c compare shipboard visual simulation with actual photography. Figure 9 compares a black and white copy of a high altitude NASA photograph using color infrared (IR) film over Washington, D.C. Since a suitable IR model/data base has not yet been developed within DMA, this image is compared to a visual reflectance data base over the same area. Note the good agreement between the features. Note also the absence of major roads such as the Capitol Beltway about Washington.



(a) DLMS Level II SAR Simulation

(b) DLMS Level II SBU SAR Simulation

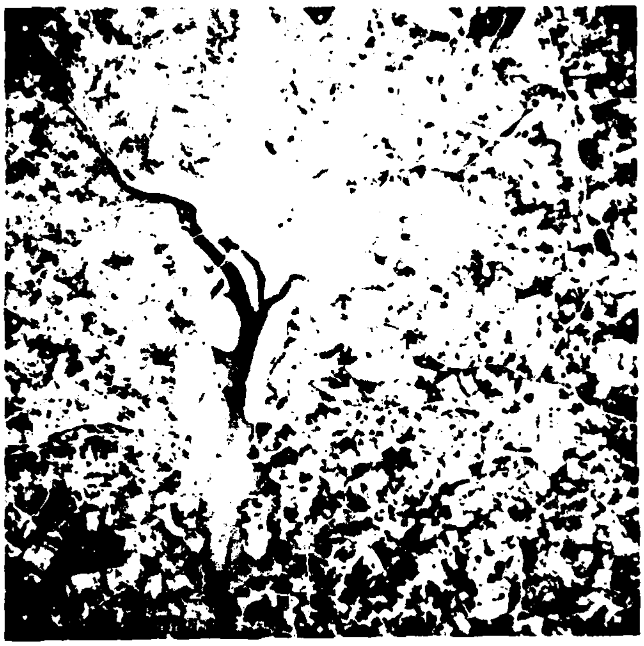
Figure 7. DLMS Synthetic Aperture Radar Simulations: Spokane, Washington

(a) Visual Simulation from 10,000 foot Altitude

(b) Visual Simulation from Shipboard Level

(c) Actual Photograph from Shipboard Level

Figure 8. Port Angeles, Washington and Mt. Olympus: Comparison Between Visual Simulations from DLMS Level I Data Bases and Actual Photography



(a) High Altitude Infra-red Photograph

(b) DLMS Level I Visual Reflectances

Figure 9. DLMS Data versus Infra-red Photography: Washington, D.C.

In order to support high resolution sensor simulation, the DMA is producing a prototype data base (reference 3) for various sensors including visual, SAR, Low Light Level TV, and IR. This data base production is for evaluation of content requirements and production cost analyses. Large area (Level V) characteristics are currently specified, but small area (Level X) specifications for high detail portrayal are not. In general, Level V supplements Level I DLMS with additional feature descriptors, additional feature identification codes such as major transportation lines, and divides concrete/asphalt into separate surface material categories. The new feature descriptors are the roof descriptor, shape code, and microdescriptor.

The roof descriptor portrays ten roof types and four monitor types, yielding 40 different roofs. The shape codes are rectangular parallelepiped, (hemi-)spherical, pyramid, cone, cylinder, and other. The microdescriptor is a multi-purpose descriptor which describes some of the visual characteristics of a feature. This may be used to support synthetic break-up in a manner more realistic than by purely random means based on statistical percentages. The microdescriptors include vertical composition information such as height and location of a tower on a building, homogeneous area information such as the predominant dimensions of smaller features aggregated into larger areal features, and pattern definition where applicable such as road/street patterns.

After completion of the prototype Level V data bases, new sensor simulation investigations will begin. Previous investigations (Faintich, 1979) demonstrated

the power of synthetic break-up in visual simulations using statistical percentages, and the new Level V data should provide for a much greater sense of realism and fidelity.

CONCLUSIONS

The DMA is continually striving within production constraints to improve the accuracy and level of detail in the DLMS data bases. Automated feature analysis techniques are being developed to aid in the collection of the data, and improved sensor simulations technology is helping to better utilize the information contained in the current DLMS data bases.

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